The Use of Road Infrastructure Data for Urban Transportation Planning: Issues and Opportunities

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Abstract: In order to maintain and improve road infrastructure in their respective jurisdictions, the state (the Minnesota DOT), region (the Metropolitan Council), and seven counties in the Twin Cities Metropolitan area develop their respective decision making (investment) processes in which federal or local funding are periodically allocated to road projects, prioritized according to their funding needs based on measured road infrastructure conditions such as pavement quality, level of service, and safety. Including such an investment process in urban transportation planning enables forecasting changes to road infrastructure in the future. Periodic road infrastructure reporting provides standards the jurisdictions maintain, as well as the measures they adopt for the management of road conditions. These measures, developed and maintained by engineers, however, are inconsistent with transportation planning models, causing difficulties in fully using infrastructure reports in planning practice. This paper addresses the issues we encountered with regard to the use of road infrastructure reports in planning practice and identifies the opportunity to improve the inter-operability and integration of infrastructure reporting with urban transportation planning.

CE Database subject headings: road conditions, infrastructure, urban transportation, urban planning

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Introduction

Travel demand on roads has been rapidly increasing in the Twin Cities region. By the year of 2005, it was estimated that over 40 billion vehicle kilometers were traveled per year in the seven-county Metropolitan Area (Minnesota Department of Transportation, 2005) and this population in this region is projected to double in twenty years (Metropolitan Inter-County Association, 2005). Accordingly the road infrastructure is expanding too. Currently there are approximately 24,000 km of roads in the metro area. The maintenance, rehabilitation, and expansion of existing road infrastructure with limited available funding challenges both state and county jurisdictions. Jurisdictions respond to this challenge in a variety of ways, characterized by the periodic decision-making process to select projects that rehabilitate, upgrade, or expand specific road segments constrained by available funding. In this process, candidate roads are scored and ranked based on their infrastructure conditions in terms of their funding needs. A project supported by Minnesota Department of Transportation (Mn/DOT) has been conducted to predict the road infrastructure of the Twin Cities twenty years hence by incorporating the stated decision (investment) processes of the state and seven counties into a transportation planning model (Levinson, Montes de Oca, and Xie, 2006).

We attempted to rely on the annual reports of conditions and performance and the databases referred to in those reports when we implemented the decision processes in our planning model, because these reports are official documents of infrastructure status required by law and they are published periodically, and because most of the decision criteria are based on the measured conditions on the road network. Most of these criteria and related measures are presented in reports prepared by each jurisdiction; these reports are often supported by electronic information systems. The specific decision making process for each jurisdiction has been ascertained by review of official documents and interviews with local officials or engineers, many of whom endorsed our conclusion (Montes de Oca and Levinson, 2006). According to the interviews, the top three priorities are safety, pavement quality, and capacity; in other words, a road with poorer pavement quality, less safety, and lower capacity (or higher utilization) will have a higher likelihood of funding.

However, inconsistencies were encountered when incorporating these decision rules into the planning model. These inconsistencies arise because the status of infrastructure is evaluated and maintained by engineers while they may be used for a transportation planning model developed by planners. This paper addresses the issues we encountered in this project with regard to the use of road infrastructure reports in planning. The inconsistencies between what infrastructure reports provide and what an urban transportation planning model needs are elaborated in three aspects: pavement quality, traffic flow, and safety. This paper provides experience about using periodic infrastructure reports in planning practice and identifies the opportunity to improve the inter-operablity and integration of infrastructure reporting with urban transportation planning.

Pavement Conditions

Road infrastructure represents the supply side of an urban transportation system. Pavement condition is a critical indicator to the quality of road infrastructure in terms of providing a smooth and reliable driving environment on roads. A series of indices have

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been developed by Mn/DOT and adopted by the state and seven counties to evaluate the pavement conditions of road segments in their respective jurisdictions: PCI (Pavement Condition Index) is scored as a perfect roadway (100 points) minus point deductions for "distresses" that are observed; PSR (Present Service-ability Rating) is measured as vertical movement per unit horizontal movement (e.g. millimeters of vertical displacement per meter of horizontal displacement) as one drives along the road; Surface Rating (SR) is calculated by reviewing images of the roadway based on the frequency and severity of defects; PQI (Pavement Quality Index) is calculated using the PSR and SR to evaluate the general condition of the road. A high PQI (up to 4.5) means a road will most likely not need maintenance soon, whereas a low PQI means it can be selected for maintenance (Hammerand, 2006).

These indices of pavement quality are basic measures for road maintenance and preservation, for which each county develops its own performance standards to evaluate pavement conditions and make decisions on maintenance and preservation projects. Typically, pavement preservation projects are prioritized based on PCI of road segments: the lower the PCI, the higher the likelihood of selection. Taking Washington County as an example (Washington County Transportation Division, 2004), the county has determined that a reasonable standard to maintain is an average PCI of 72. Thus any road segment with its PCI below 72 has a chance to be selected for preservation. Dakota County, on the other hand, scores its preservation projects according to the measure of PQI: a road segment will be allocated 17 points (out of a possible 100) if its PQI falls lower than 3.1.

The first step to include these decision rules is to obtain the measures of pavement quality for each link in the planning road network. The pavement data in their original format was obtained from Mn/DOT's Pavement Management Unit. However this data structure is incompatible with the link-node structure of the planning road network used by the Metropolitan Council and other planning agencies. In the original dataset, the measures of PCI, PSR, and PQI are stored in records indexed by "highway segment numbers" along each highway route. Highway sections with the same highway segment number are differentiated by their starting and ending stations. There is no exact match between highway segments in the actual road network and links in the planning network, as stationing is a position along the curved centerline of a highway while a planning network is a simplified structure consisting of only straight lines intersecting at points. Conversion between two formats is expensive and some segments with pavement data will have no corresponding link ID due to the simplification of geometry in a planning network. The pavement data is only available in a consistent electronic database for state-owned roads; counties have not constructed complete databases for their roads. Consequently, pavement data in their current format could not easily or accurately be integrated with our transportation planning model.

Moreover, historic pavement data are not available in electronic format, although the information on pavement history such as pavement life and the duration since last repaving are important to estimate the cost of a preservation project, also affecting the decision whether a specific project will get selected and how much funding will be allocated.

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Traffic Flow

Traffic conditions reflect the travel demand loaded on a given road infrastructure. Traffic flows on roads, together with road capacity, can be used to calculate the volume/capacity (V/C) ratio, which is an approximate indicator for the level of service of road infrastructure, and is commonly adopted by the jurisdictions in their respective decision making processes. The traffic flows on the planning road network are predicted by the transportation planning model, but the results have to be calibrated with actual traffic data.

Loop detection is the primary technology currently employed in Minnesota to collect actual traffic data. About one thousand detector stations have been buried on major highways in the Twin Cities, through which Mn/DOT's Traffic Management Center collects, stores, and makes public traffic data every 30 seconds, including measured volume (flow) and occupancy, and calculated speed data for each detector station. Although the estimates of Annual Average Daily Traffic (AADT) for the planning road network are readily available, loop detectors provide more accurate measures of traffic volume, since they are collecting real-time data on a continuous basis. It also allows for calibrating models to hourly rather than daily conditions.

Due to the limited ability to convert raw data collected by loop detectors, however, most forecasting models rely on AADT data. The raw data are stored in a 30-second interval in binary codes. For planning uses they have to be converted and aggregated into desired measures, such as peak hour average, average for a particular month or a particular season, etc, in a systematic way. However, neither Mn/DOT nor Metropolitan Council provides such a tool or any standards to do so. University of Minnesota did develop some software primarily for academic uses (Kwon and Dhruv, 2004; Xin *et al*., 2006), but the process is still extremely time-consuming and defective detectors can't be efficiently handled. In our case, in order to calibrate our model using peak period (7:00 – 9:00 am) traffic, we randomly selected 10% of detector stations and were able to use only 70% of those because of defective detectors (although most defects are temporary). To save time, the raw data were processed only for one month.

Another issue in integrating loop detector data into a planning road network is to match the detector stations with the links. Similar to the problem encountered in translating pavement data, detectors are located along major highways and mapped on the actual geometry of the network, while the planning road network is a simplified structure with only straight lines. However the issue is more difficult because loop detectors in the database, while topologically correct, are not geographically correct. This data structure is convenient for the primary users of the data, but inconvenient to reuse for transportation forecasting purposes. We had to correlate detector station number with link ID manually, which required an immense amount of time. In most cases, the correlation is straightforward where the two networks overlap; but sometimes it is entangled, especially where a complex interchange is simplified and ramps are offset in the planning road network. It is surprising that with the potential use of loop detector data for the calibration of planning models, no official documentation such as a relationship table has been found to correlate detector station numbers with link IDs.

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Safety

As aforementioned, safety is an important indicator to the performance of road infrastructure, and it is one of the most important issues that planners look at when evaluating road conditions and selecting projects to improve road infrastructure. Jurisdictions may develop different safety criteria in their decision making process. For example, Scott County allocates 50 points to a project if is among the 200 high crash locations, while Hennepin County allocates points to a project according to the ratio of crash rate at the location to the average county rate by road type. GIS technology was essential to incorporate crashes into a planning road network. The crash database included the geographic location of each crash. Crashes for every year were mapped as points in the planning road network and were attached to their nearest links. The crash rate was then calculated as the crash counts of a link over segment length multiplied by traffic volume that traversed the link in certain duration.

Conclusions

Imagining engineers and planners are using different geometries of the same network for their own convenience, it is not hard to explain these inconsistencies we experienced in using road infrastructure reports and databases for planning purposes. Both sides are intuitively reasonable: evaluating and reporting road conditions on the actual geometry makes senses to engineers because the pavement is sampled and its quality is measured section by section along actual routes, loop detectors are buried on actual highways, and crashes are detected and recorded on actual roads. On the other hand, a simplified link-node structure makes modeling much easier for transportation planners without losing too much accuracy. Without changing the way engineers and planners are doing business, correlation between different formats, such as highway segment number versus link ID and detector station number versus link ID, should be officially established and made public in order to expedite use of the databases on road conditions in planning practice. A standard reference to original databases and easy links to online resources in road infrastructure reports are also recommended for the better of use of data sources.

References

Hammerand, J. (2006). “Rating Minnesota’s Roads.” *The Minnesota Local Technical Assistance Program (LTAP): Technology Exchange, vol.24, No.1, 3*

Kwon, T.M., and N. Dhruv (2004). “Unified Transportation Sensor Data Format (UTSDF) for Efficient Archiving and Sharing of Statewide Transportation Sensor Data.” *Proc. of the Transportation Research Board 83rd Annual Meeting*.

Levinson, D., Montes de Oca, N., and Xie, F. (2006). “Beyond Business as Usual: Ensuring the Network We Want is the Network We Get.” *Final Report for TAP Meeting May 30th, 2006*

Minnesota Metropolitan Inter-County Association (2005). “Driving Minnesota’s Economic Vitality: The Need to Invest in Our Transportation System.”

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<http://www.mica.org/2005MICA%20Main%20brochure.pdf, 2-3> (May 20, 2006).

Minnesota Department of Transportation (2005). Official Website: <http://www.dot.state.mn.us/tda/html/faq.html> (May 20, 2006)

Montes de Oca, N., and Levinson, D. (2006). "Network Expansion Decision-making in the Twin Cities." *Journal of the Transportation Research Board: Transportation Research Record, in press.*

Washington County Transportation Division (2004). "Washington County Annual Performance Report for 2004." <http://www.co.washington.mn.us/client_files/documents/adm/PerfMeas-2004//ADM-PM-04-Transportation.pdf> (May 20, 2006)

Xin,W., Hordakis J., and Michalopoulos, P.G. (2006). "Preprocessing Volume Data for Improved Simulation." *Proc. of the Transportation Research Board 85th Annual Meeting*.

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